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Yamaguchi

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(54) **SIGNAL PROCESSING APPARATUS, SIGNAL PROCESSING METHOD AND COMPUTER READABLE MEDIUM**

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A61B 1/00	(2006.01)
A61B 1/06	(2006.01)
A61B 5/00	(2006.01)

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CPC ***G01J 3/51*** (2013.01); ***A61B 1/00009*** (2013.01); ***A61B 1/0638*** (2013.01); ***A61B 5/0059*** (2013.01); ***A61B 5/0084*** (2013.01); ***G01J 3/513*** (2013.01); *A61B 5/441* (2013.01)

(58) **Field of Classification Search**

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See application file for complete search history.

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(57) **ABSTRACT**

A signal processing apparatus includes an optical intensity detecting section that detects an intensity of light from a subject at a first wavelength and a second wavelength, where the first wavelength is different from the second wavelength, a pigment component identifying section that identifies a pigment component in the light from the subject, based on (i) a difference between a first absorptance of the subject at the first wavelength and a second absorptance of the subject at the second wavelength and (ii) a difference between the intensity at the first wavelength and the intensity at the second wavelength that are detected by the optical intensity detecting section, and an illumination light component identifying section that identifies an illumination light component in the light from the subject, based on a subject image obtained by image-capturing the subject and the pigment component identified by the pigment component identifying section.

14 Claims, 8 Drawing Sheets

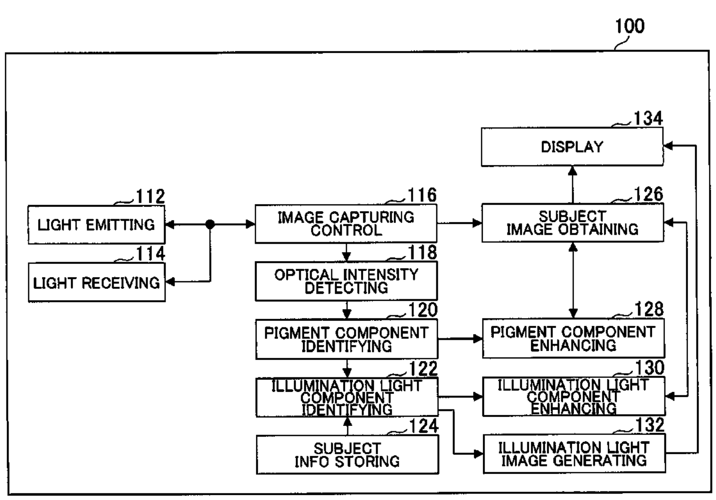

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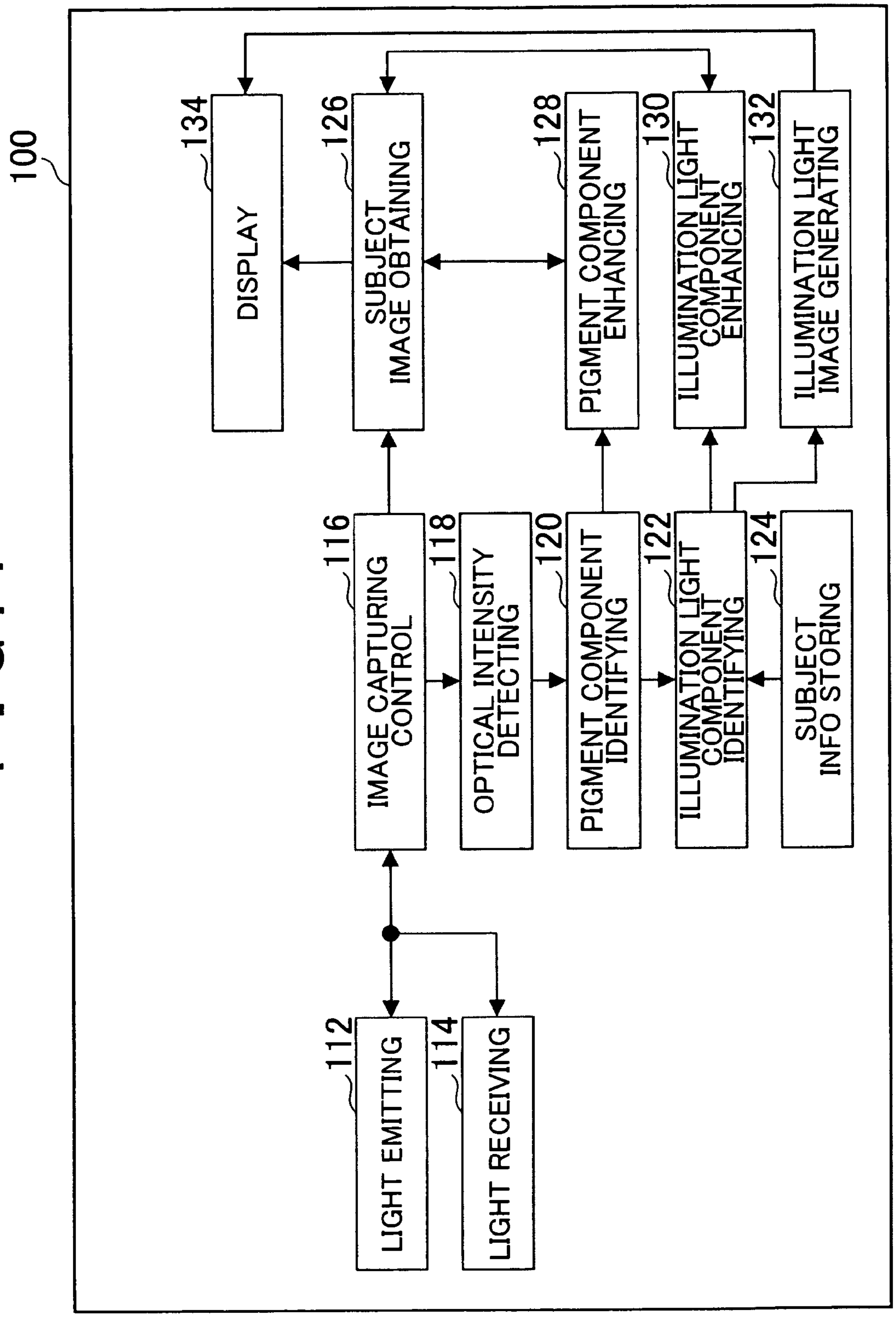
FIG. 1


100
112 LIGHT EMITTING
114 LIGHT RECEIVING
116 IMAGE CAPTURING CONTROL
118 OPTICAL INTENSITY DETECTING
120 PIGMENT COMPONENT IDENTIFYING
122 ILLUMINATION LIGHT COMPONENT IDENTIFYING
124 SUBJECT INFO STORING
126 SUBJECT IMAGE OBTAINING
128 PIGMENT COMPONENT ENHANCING
130 ILLUMINATION LIGHT COMPONENT ENHANCING
132 ILLUMINATION LIGHT IMAGE GENERATING
134 DISPLAY

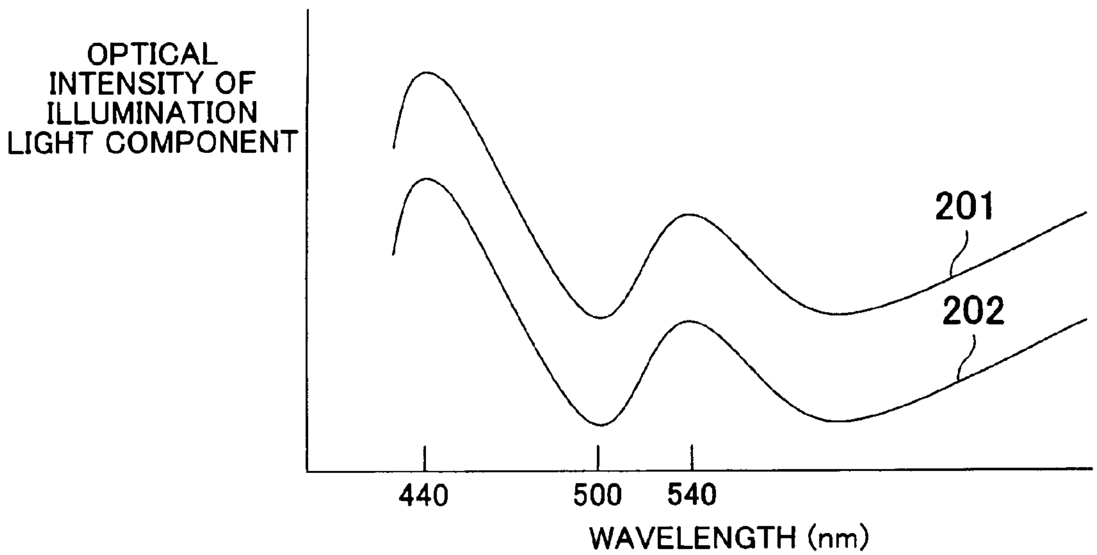

OPTICAL
INTENSITY OF
ILLUMINATION
LIGHT COMPONENT
201
202
440
500
540
WAVELENGTH (nm)

FIG. 2

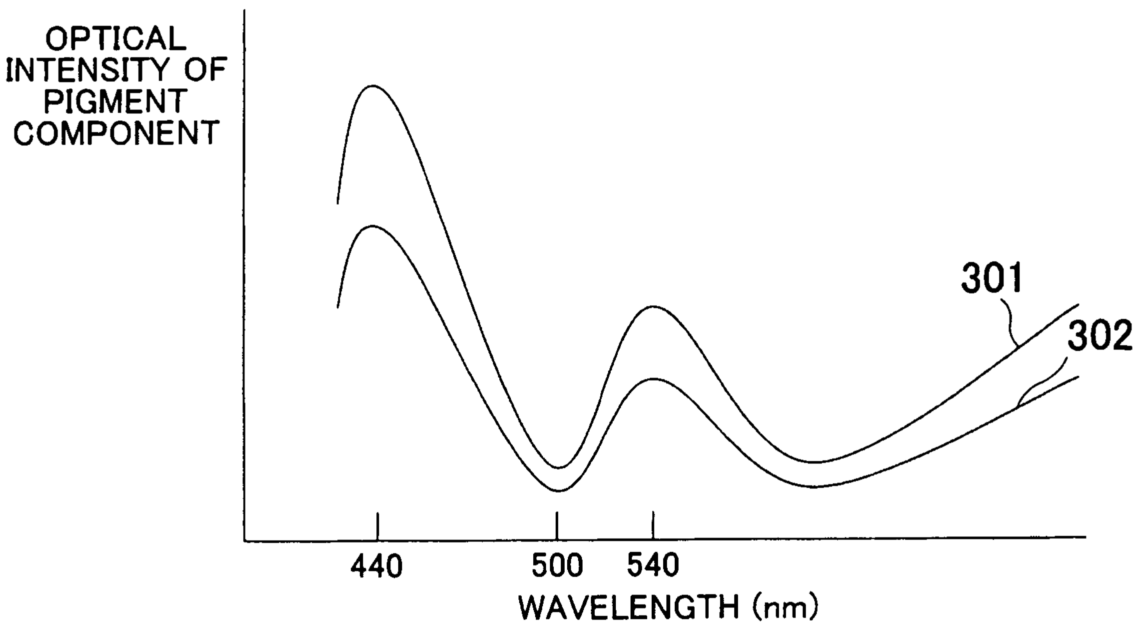

OPTICAL INTENSITY OF PIGMENT COMPONENT
301
302
440
500
540
WAVELENGTH (nm)

FIG. 3

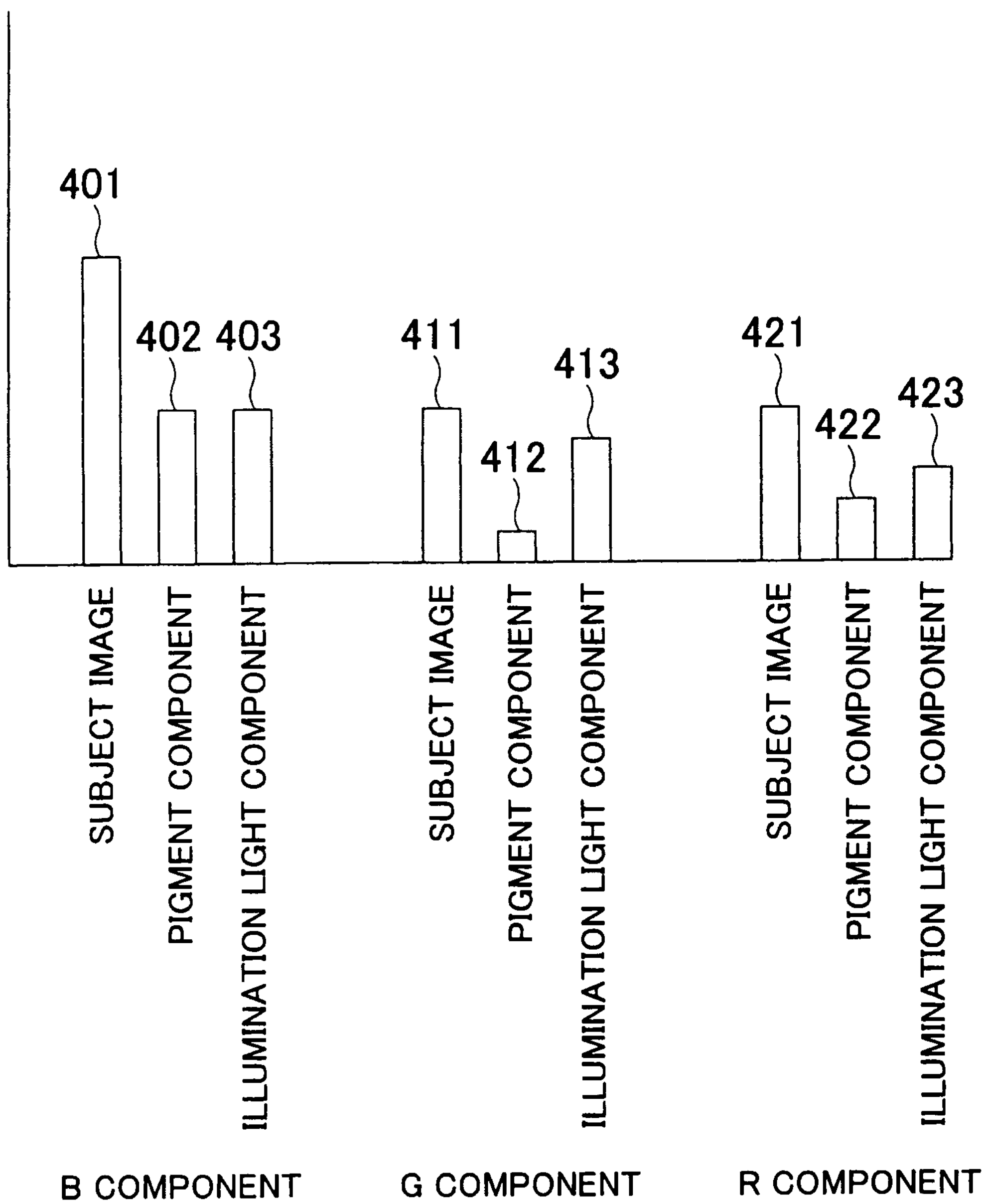

401
402
403
411
412
413
421
422
423
SUBJECT IMAGE
PIGMENT COMPONENT
ILLUMINATION LIGHT COMPONENT
SUBJECT IMAGE
PIGMENT COMPONENT
ILLUMINATION LIGHT COMPONENT
SUBJECT IMAGE
PIGMENT COMPONENT
ILLUMINATION LIGHT COMPONENT
B COMPONENT
G COMPONENT
R COMPONENT

FIG. 4

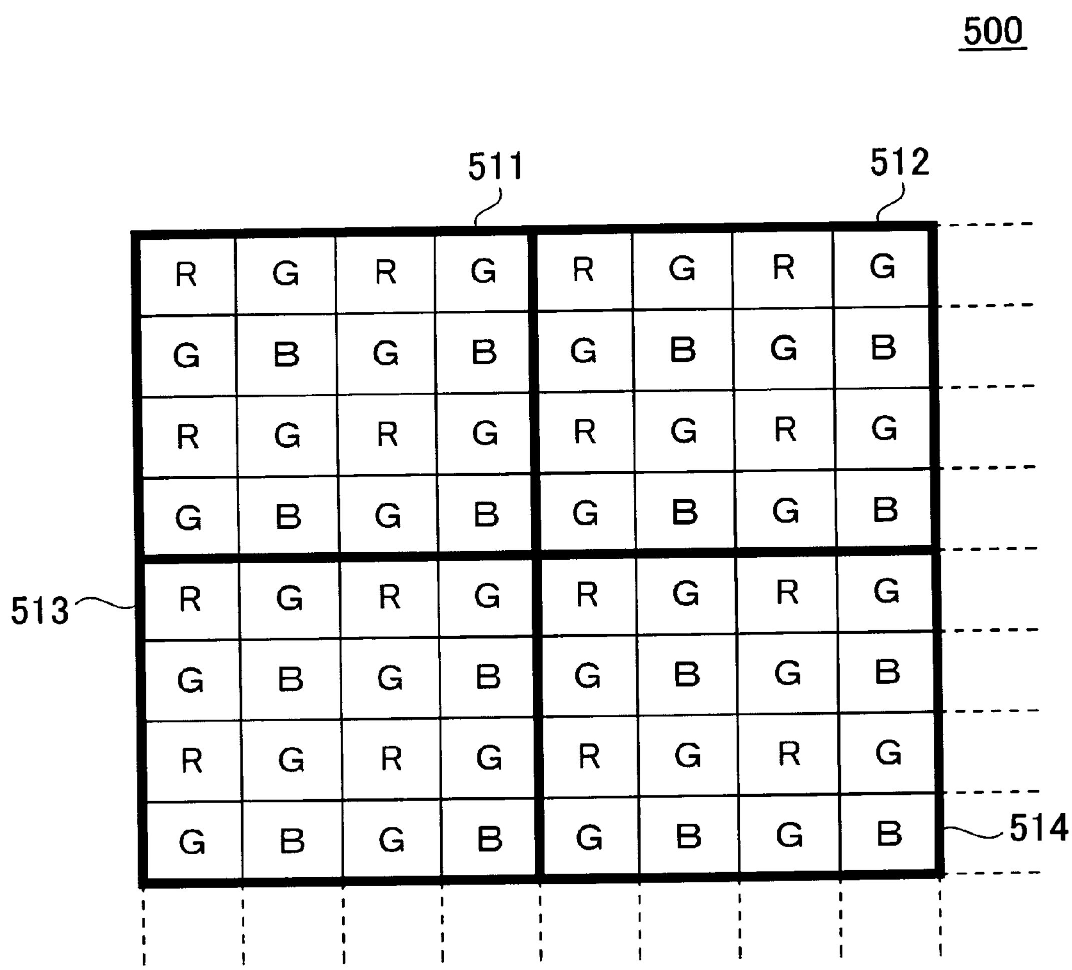

500
511
512
513
514
R G R G R G R G
G B G B G B G B
R G R G R G R G
G B G B G B G B
R G R G R G R G
G B G B G B G B
R G R G R G R G
G B G B G B G B

FIG. 5

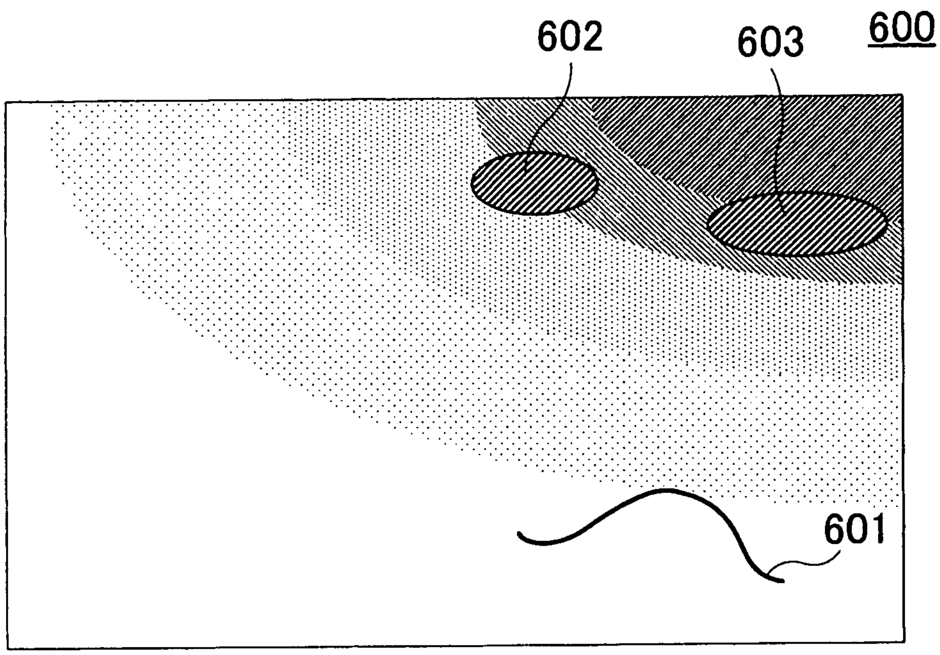


FIG. 6

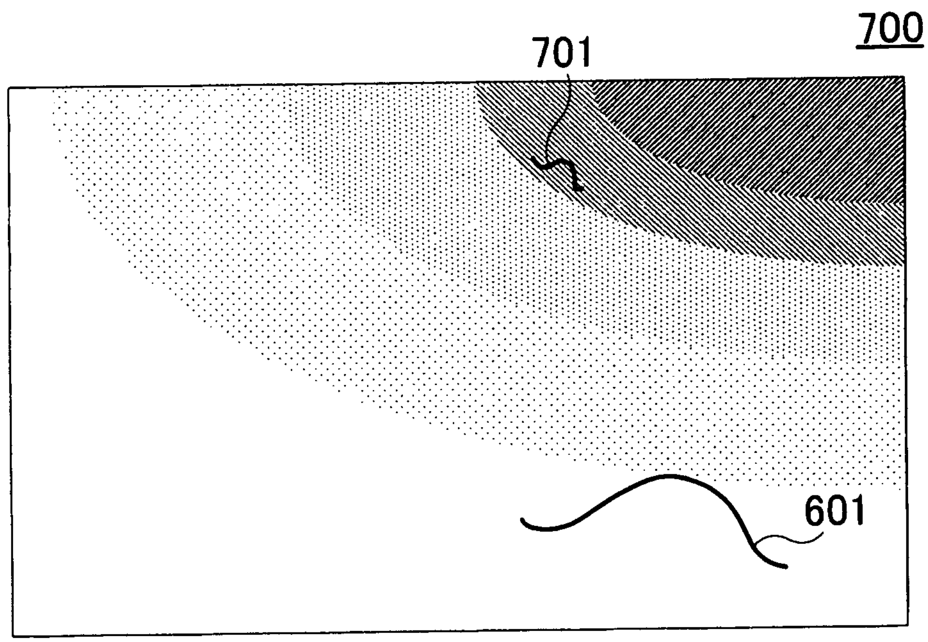


FIG. 7

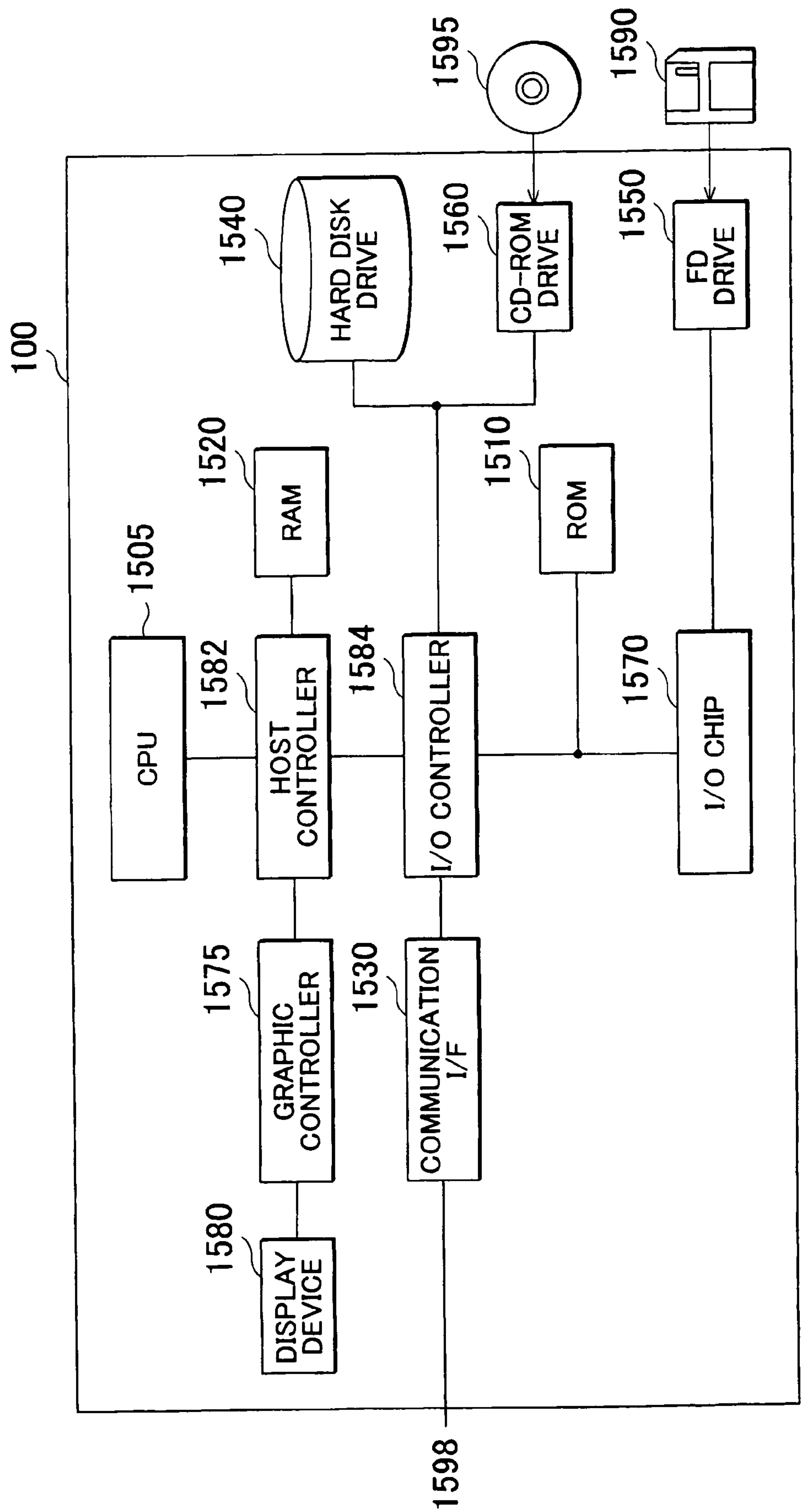

100
1595
1590
1540
HARD DISK DRIVE
1560
CD-ROM DRIVE
1550
FD DRIVE
1520
RAM
1510
ROM
1505
CPU
1582
HOST CONTROLLER
1584
I/O CONTROLLER
1570
I/O CHIP
1575
GRAPHIC CONTROLLER
1530
COMMUNICATION I/F
1580
DISPLAY DEVICE
1598

FIG. 8

SIGNAL PROCESSING APPARATUS, SIGNAL PROCESSING METHOD AND COMPUTER READABLE MEDIUM

CROSS REFERENCE TO RELATED APPLICATION

The present application claims priority from a Japanese Patent Application No. 2008-095956 filed on Apr. 2, 2008, the contents of which are incorporated herein by reference.

BACKGROUND

1. Technical Field

The present invention relates to a signal processing apparatus, a signal processing method, and a computer readable medium storing thereon a program. More particularly, the present invention relates to a signal processing apparatus and a signal processing method for identifying an illumination light component in light received from a subject, and to a computer readable medium storing thereon a program for use with the signal processing apparatus.

2. Related Art

A technique is devised to generate an image signal without an illumination light reflection component by detecting a difference between two visual signals formed by light having two different wavelengths at which an observation target exhibits different light absorption characteristics, as disclosed, for example, in Japanese Patent No. 2643941. Another technique is devised to measure a concentration of a light absorbing substance in a blood without being affected by a change in oxygen saturation, by referring to a light attenuation ratio among a plurality of different wavelengths, as disclosed, for example, in Japanese Patent No. 3972176. Yet another technique is devised to generate a differential image representing a distribution of oxygenated hemoglobin by detecting a difference in two images formed by light of two different wavelengths for which oxygenated hemoglobin exhibits different light reflection characteristics, as disclosed, for example, in Japanese Patent Application Publication No. 2002-272744. Yet another technique is devised to capture a band image of a discrete spectral distribution of a subject by limiting a wavelength range of illumination light used to irradiate the subject, as disclosed, for example, in Japanese Patent Application Publication No. 2002-95635.

These techniques, however, are incapable of producing an image without influence of a pigment of a subject. An image of a living organism cannot be used to accurately judge a condition of an uneven shape such as a lesion of the surface of the living organism before influence of hemoglobin, which is a pigment of the living organism, is eliminated.

SUMMARY

Therefore, it is an object of an aspect of the innovations herein to provide a signal processing apparatus, a signal processing method and a computer readable medium, which are capable of overcoming the above drawbacks accompanying the related art. The above and other objects can be achieved by combinations described in the independent claims. The dependent claims define further advantageous and exemplary combinations of the innovations herein.

According to the first aspect related to the innovations herein, one exemplary signal processing apparatus may include a signal processing apparatus for separating light from a specified subject into an illumination light component and a pigment component, where the illumination light component results from a color of light with which the subject is irradiated, and the pigment component results from a color of a pigment of the subject. The signal processing apparatus includes an optical intensity detecting section that detects an intensity of the light from the subject at a first wavelength and a second wavelength, where the first wavelength is different from the second wavelength, a pigment component identifying section that identifies the pigment component in the light from the subject, based on (i) a difference between a first absorptance of the subject at the first wavelength and a second absorptance of the subject at the second wavelength and (ii) a difference between the intensity at the first wavelength and the intensity at the second wavelength that are detected by the optical intensity detecting section, and an illumination light component identifying section that identifies the illumination light component in the light from the subject, based on a subject image obtained by image-capturing the subject and the pigment component identified by the pigment component identifying section.

The summary clause does not necessarily describe all necessary features of the embodiments of the present invention. The present invention may also be a sub-combination of the features described above. The above and other features and advantages of the present invention will become more apparent from the following description of the embodiments taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an exemplary block configuration of an image capturing apparatus **100** relating to an embodiment of the present invention.

FIG. **2** illustrates exemplary frequency characteristics of an illumination light component in light from a subject.

FIG. **3** illustrates exemplary frequency characteristics of a pigment component in the light from the subject.

FIG. **4** illustrates exemplary color components contained in a subject image obtained by a subject image obtaining section **126**.

FIG. **5** illustrates exemplary partial regions, in each of which the pigment component and the illumination light component are identified.

FIG. **6** illustrates an example of the subject image obtained by the subject image obtaining section **126**.

FIG. **7** illustrates an example of an image generated by an illumination light image generating section **132**.

FIG. **8** illustrates an exemplary hardware configuration of the image capturing apparatus **100**.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

Some aspects of the invention will now be described based on the embodiments, which do not intend to limit the scope of the present invention, but exemplify the invention. All of the features and the combinations thereof described in the embodiment are not necessarily essential to the invention.

FIG. **1** illustrates an exemplary block configuration of an image capturing apparatus **100** relating to an embodiment of the present invention. The following description is made with an assumption that the image capturing apparatus **100** is an example of a signal processing apparatus.

The image capturing apparatus **100** separates light from a specified subject into an illumination light component and a pigment component. The illumination light component results from the color of light with which the subject is irradiated. The pigment component results from the color of a pigment of the subject. The illumination light component may be a surface reflection component, which is a component of the light reflected by the surface of the subject. In other words, the image capturing apparatus **100** may separate the light from the specified subject into the surface reflection component and the pigment component.

The image capturing apparatus **100** includes a light emitting section **112**, a light receiving section **114**, an image capturing control section **116**, an optical intensity detecting section **118**, a pigment component identifying section **120**, an illumination light component identifying section **122**, and a subject information storing section **124**. Furthermore, the image capturing apparatus **100** includes a subject image obtaining section **126**, a pigment component enhancing section **128**, an illumination light component enhancing section **130**, an illumination light image generating section **132**, and a display section **134**.

The image capturing apparatus **100** may be an endoscope. When the image capturing apparatus **100** is an endoscope, the light emitting section **112** and the light receiving section **114** may be provided in the end of an insert portion of the endoscope, which is to be inserted into a living organism. In a different example, the light emitting section **112** may be provided outside the insert portion and send light to the living organism through a light guide provided in the insert portion of the endoscope. The light receiving section **114** may be provided outside the insert portion and receive light from the living organism through the light guide provided in the insert portion of the endoscope.

The light emitting section **112** emits light to a subject. Specifically speaking, the light emitting section **112** emits light having a first wavelength at which the subject exhibits a minimal light absorption characteristic. For example, the light emitting section **112** emits, as an example of the light having the first wavelength, light having a wavelength of 440 nm at which hemoglobin exhibits a minimal light absorption characteristic. The light emitting section **112** also emits light having a second wavelength at which the subject exhibits a maximal light absorption characteristic. For example, the light emitting section **112** emits, as an example of the light having the second wavelength, light having a wavelength of 500 nm at which hemoglobin exhibits a maximal light absorption characteristic.

The light emitting section **112** may emit wideband light including the first and second wavelengths, which is used to detect the intensities of the light having the first wavelength and the light having the second wavelength. For example, the light emitting section **112** may emit white light, which is used to detect the intensities of the light having the first wavelength and the light having the second wavelength.

The light emitting section **112** may include a first light emitting element that emits the light having the first wavelength and a second light emitting element that emits the light of the second wavelength. The light emitting section **112** may include a first emission filter that transmits the first wavelength and a second emission filter that transmits the second wavelength.

The light emitting section **112** may further emit wideband light, which is used to capture a subject image. For example, the light emitting section **112** may further emit white light, which is used to capture a subject image.

The light receiving section **114** receives light from the subject. Specifically speaking, the light receiving section **114** receives light having the first wavelength and light having the second wavelength, which are used to detect the intensities of the light having the first wavelength and the light having the second wavelength. For example, the light receiving section **114** receives light having a wavelength of 440 nm and light having a wavelength of 500 nm, where the former is shown as an example of the light having the first wavelength and the latter is shown as an example of the light having the second wavelength, which are used to detect the intensities of the light having the first wavelength and the light having the second wavelength.

The light receiving section **114** may include a plurality of first light receiving elements for receiving the light having the first wavelength and a plurality of second light receiving elements for receiving the light having the second wavelength. In compliance with this configuration, the light receiving section **114** may include a plurality of first reception filters that mainly transmit the light having the first wavelength and a plurality of second reception filters that mainly transmit the light having the second wavelength. In place of the first and second light receiving elements, the light receiving section **114** may include a first light measuring section that detects the intensity of the light having the first wavelength and a second light measuring section that detects the intensity of the light having the second wavelength.

The light receiving section **114** may be a CCD or CMOS in which the first and second light receiving elements are regularly arranged. In a different example, the first light receiving elements may form a CCD or CMOS and the second light receiving elements may form a different CCD or CMOS.

The light receiving section **114** may further receive wideband light from the subject, which is used to capture a subject image. For example, the light receiving section **114** may further receive white light from the subject, which is used to capture a subject image.

The light receiving section **114** may further include a plurality of light receiving elements for receiving the wideband light from the subject, which is used to capture a subject image. The light receiving section **114** may further include a plurality of color-specific light receiving elements for receiving the respective color components of the wideband light from the subject, which is used to capture a subject image. For example, the light receiving section **114** may further include a plurality of color-specific light receiving elements for separately receiving the R, G and B components of the wideband light from the subject, which is used to capture a subject image.

The image capturing control section **116** controls the light emission timing of the light emitting section **112**. For example, the image capturing control section **116** may control the light emitting section **112** to alternately emit the light having the first wavelength and the light having the second wavelength. The image capturing control section **116** may control the light emitting section **112** to simultaneously emit the light having the first wavelength and the light having the second wavelength.

The image capturing control section **116** may control the light emitting section **112** to sequentially emit the light having the first wavelength, the light having the second wavelength and the wideband light used to capture a subject image. When the light receiving section **114** can simultaneously receive the light having the first wavelength in the wideband light, the light having the second wavelength in the wideband light, and the wideband light used to capture a subject image, the image capturing control section **116** may control the light emitting section **112** to only emit the wideband light.

The image capturing control section **116** controls the light reception timing of the light receiving section **114**. For example, the image capturing control section **116** may control the light receiving section **114** to alternately receive the light having the first wavelength and the light having the second wavelength. The image capturing control section **116** may control the light receiving section **114** to simultaneously receive the light having the first wavelength and the light having the second wavelength.

When the light emitting section **112** sequentially emits the light having the first wavelength, the light having the second wavelength, and the wideband light used to capture a subject image, the image capturing control section **116** may control the light receiving section **114** to sequentially receive the light having the first wavelength, the light having the second wavelength, and the wideband light used to capture a subject image. In this manner, the image capturing control section **116** may sequentially capture an image based on the light having the first wavelength, an image based on the light having the second wavelength, and the subject image.

On the other hand, when the light emitting section **112** only emits wideband light, the image capturing control section **116** may control the light receiving section **114** to simultaneously receive the light having the first wavelength in the wideband light, the light having the second wavelength in the wideband light, and the wideband light. In this manner, the image capturing control section **116** may simultaneously capture an image based on the light having the first wavelength, an image based on the light having the second wavelength, and the subject image.

The optical intensity detecting section **118** detects the intensities at the first and second wavelengths of the light from the subject. Specifically speaking, the optical intensity detecting section **118** detects the intensity at the first wavelength, at which the subject exhibits a minimal light absorption characteristic, and the intensity at the second wavelength, at which the subject exhibits a maximal absorption characteristic. The optical intensity detecting section **118** may detect the intensities of the light having the first wavelength and the light having the second wavelength that are respectively received by the light receiving section **114**.

The subject information storing section **124** stores color information to identify the pigment component in the light from the subject. For example, the subject information storing section **124** may store color information of the subject in association with a first difference between a first absorptance and a second absorptance of the subject and a second difference between the intensity of the light having the first wavelength and the intensity of the light having the second wavelength, which are detected by the optical intensity detecting section **118**. Here, the first absorptance indicates the absorptance of the subject for the light having the first wavelength, and the second absorptance indicates the absorptance of the subject for the light having the second wavelength.

The subject information storing section **124** may store color information defining the intensities of the respective color components. For example, the subject information storing section **124** may store color information indicating the intensities of the B, G and R components.

The pigment component identifying section **120** identifies the pigment component in the light from the subject, based on the first difference between the first absorptance and the second absorptance of the subject and the second difference between the intensity of the light having the first wavelength and the intensity of the light having the second wavelength, which are detected by the optical intensity detecting section **118**. The pigment component identifying section **120** may identify the pigment component in the light from the subject, based on the color information stored in the subject information storing section **124**. For example, the pigment component identifying section **120** may calculate the first difference and the second difference, and then obtain from the subject information storing section **124** the color information associated with the calculated first and second differences.

The pigment component identifying section **120** may use, as the first difference, the ratio between the first absorptance of the subject for the light having the first wavelength and the second absorptance of the subject for the light having the second wavelength. The pigment component identifying section **120** may use, as the second difference, the ratio between the intensity of the light having the first wavelength and the intensity of the light having the second wavelength, both of which are detected by the optical intensity detecting section **118**.

The first absorptance may be calculated in advance based on the amount of the light having the first wavelength with which the subject is irradiated and the amount of the light having the first wavelength reflected by the subject. The pigment component identifying section **120** may obtain the first absorptance from a recording medium such as a memory that prestores the first absorptance.

The second absorptance may be calculated in advance based on the amount of the light having the second wavelength with which the subject is irradiated and the amount of the light having the second wavelength reflected by the subject. The pigment component identifying section **120** may obtain the second absorptance from a recording medium such as a memory that prestores the second absorptance.

The subject image obtaining section **126** obtains the subject image showing the subject. For example, the subject image obtaining section **126** obtains the subject image captured under the control performed by the image capturing control section **116**. The subject image obtaining section **126** may obtain, as the subject image, an image containing a plurality of color components. For example, the subject image obtaining section **126** may obtain, as the subject image, a color image containing the R, G and B components.

The subject image obtaining section **126** may obtain the subject image containing a single color component. For example, the subject image obtaining section **126** may obtain, as the subject image, a black-and-white image containing the B component. The subject image obtaining section **126** may obtain, as the subject image, a black-and-white image containing the G component.

The subject image obtaining section **126** may obtain, as the subject image, an image based on the light having the first wavelength received by the light receiving section **114**. For example, the subject image obtaining section **126** may obtain, as the subject image, an image based on light having a wavelength of 440 nm received by the light receiving section **114**.

The subject image obtaining section **126** may obtain, as the subject image, an image based on the light having the second wavelength received by the light receiving section **114**. For example, the subject image obtaining section **126** may obtain, as the subject image, an image based on light having a wavelength of 500 nm received by the light receiving section **114**.

The illumination light component identifying section **122** identifies the illumination light component in the light from the subject, based on the subject image obtained by the subject image obtaining section **126** and the pigment component identified by the pigment component identifying section **120**. The illumination light component identifying section **122** may identify the illumination light component in the light from the subject, by subtracting the color information of the pigment component identified by the pigment component identifying section **120** from the color information of the subject image obtained by the subject image obtaining section **126**.

The illumination light component identifying section **122** may identify the illumination light component in the light from the subject, for each of the partial regions obtained by dividing the subject image. For example, the optical intensity detecting section **118** may detect, for each partial region, the intensity of the light having the first wavelength and the intensity of the light having the second wavelength. The pigment component identifying section **120** may identify, for each partial region, the pigment component in the light from the subject. The illumination light component identifying section **122** may identify, for each partial region, the illumination light component in the light from the subject. For example, the illumination light component identifying section **122** may identify the illumination light component in the light from the subject, in each partial region having 2×2, 4×4, or 8×8 pixels.

The pigment component enhancing section **128** enhances color information of the pigment component identified by the pigment component identifying section **120** in the subject image obtained by the subject image obtaining section **126**. The pigment component enhancing section **128** may increase the intensity of the pigment component identified by the pigment component identifying section **120** in the subject image obtained by the subject image obtaining section **126**. The pigment component enhancing section **128** may enhance the intensity of a single color component in the subject image obtained by the subject image obtaining section **126**. For example, the pigment component enhancing section **128** may enhance the intensity of the G component in the subject image obtained by the subject image obtaining section **126**.

The illumination light component enhancing section **130** enhances color information of the illumination light component identified by the illumination light component identifying section **122** in the subject image obtained by the subject image obtaining section **126**. The illumination light component enhancing section **130** may increase the intensity of the illumination light component identified by the illumination light component identifying section **122** in the subject image obtained by the subject image obtaining section **126**. The illumination light component enhancing section **130** may enhance the intensity of a single color component in the subject image obtained by the subject image obtaining section **126**. For example, the illumination light component enhancing section **130** may enhance the intensity of the B component in the subject image obtained by the subject image obtaining section **126**.

The illumination light image generating section **132** generates an image of the illumination light component identified by the illumination light component identifying section **122**, by using the subject image obtained by the subject image obtaining section **126** and the pigment component identified by the pigment component identifying section **120**. The illumination light image generating section **132** may generate the image of the illumination light component identified by the illumination light component identifying section **122**, by subtracting the color information of the pigment component identified by the pigment component identifying section **120** from the color information of the subject image obtained by the subject image obtaining section **126**.

The display section **134** displays a variety of images. For example, the display section **134** displays the subject image obtained by the subject image obtaining section **126**. The display section **134** may display the image of the illumination light component generated by the illumination light image generating section **132**. The display section **134** may achieve pseudo color display for the image of the illumination light component generated by the illumination light image generating section **132**.

The display section **134** may display the subject image containing a plurality of color components. For example, the display section **134** may display the subject image containing the R, G and B components. The display section **134** may display the subject image containing a single color component. For example, the display section **134** may display the subject image containing the B component. Alternatively, the display section **134** may display the subject image containing the G component. The display section **134** may achieve pseudo color display for the subject image containing a single color component.

The display section **134** may display the subject image whose illumination light component is enhanced by the illumination light component enhancing section **130**. The display section **134** may display the subject image whose pigment component is enhanced by the pigment component enhancing section **128**. The display section **134** may switch the display between the subject image whose illumination light component is enhanced by the illumination light component enhancing section **130** and the subject image whose pigment component is enhanced by the pigment component enhancing section **128**. The display section **134** may switch the display between the subject image obtained by the subject image obtaining section **126** and the image generated by the illumination light image generating section **132**.

FIG. **2** illustrates exemplary frequency characteristics of the illumination light component in the light from the subject. In the graph shown in FIG. **2**, the horizontal axis represents the wavelength of the light, and the vertical axis represents the intensity of the illumination light component of the light from the subject. Frequency characteristics **201** and **202** each show the frequency characteristic of the illumination light component in the light from the subject. The frequency characteristics **201** and **202** are obtained by irradiating the subject with irradiation light having different intensities.

The frequency characteristics **201** and **202** each take a maximal value at the wavelength of 440 nm. Also, the frequency characteristics **201** and **202** each take a minimal value at the wavelength of 500 nm.

In other words, the frequency characteristics **201** and **202** indicate that the light absorption characteristic exhibits a minimal value at the wavelength of 440 nm for the illumination light component. Also, the frequency characteristics **201** and **202** indicate that the light absorption characteristic exhibits a maximal value at the wavelength of 500 nm for the illumination light component.

Here, the difference between the optical intensity shown by the frequency characteristic **201** and the optical intensity shown by the frequency characteristic **202** stays substantially constant at any wavelength. This means that the frequency characteristic of the illumination light component in the light from the subject does not vary depending on the intensity of the irradiation light with which the subject is irradiated. Therefore, when the first wavelength is set at 440 nm and the second wavelength is set at 500 nm, the difference in the optical intensity of the illumination light component in the light from the subject between the first wavelength and the second wavelength does not vary depending on the intensity of the irradiation light with which the subject is irradiated and thus remains substantially constant.

FIG. **3** illustrates exemplary frequency characteristics of the pigment component in the light from the subject. In the graph shown in FIG. **3**, the horizontal axis represents the wavelength of the light, and the vertical axis represents the optical intensity of the pigment component of the light from the subject. Frequency characteristics **301** and **302** each show the frequency characteristic of the pigment component in the light from the subject. The frequency characteristics **301** and **302** are obtained by irradiating the subject with irradiation light having different intensities.

The frequency characteristics **301** and **302** each take a maximal value at the wavelength of 440 nm, similarly to the frequency characteristics of the illumination light component in the light from the subject. Also, the frequency characteristics **301** and **302** each take a minimal value at the wavelength of 500 nm, similarly to the frequency characteristics of the illumination light component in the light from the subject.

In other words, the frequency characteristics **301** and **302** indicate that the light absorption characteristic exhibits a minimal value at the wavelength of 440 nm for the pigment component. Also, the frequency characteristics **301** and **302** indicate that the light absorption characteristic exhibits a maximal value at the wavelength of 500 nm for the pigment component.

Here, the difference between the optical intensity shown by the frequency characteristic **301** and the optical intensity shown by the frequency characteristic **302** varies depending on the wavelength. This means that the frequency characteristic of the pigment component in the light from the subject varies depending on the intensity of the irradiation light with which the subject is irradiated. Therefore, when the first wavelength is set at 440 nm and the second wavelength is set at 500 nm, the difference in the optical intensity of the pigment component in the light from the subject between the first wavelength and the second wavelength varies depending on the intensity of the irradiation light with which the subject is irradiated and thus is not constant.

As is apparent from FIGS. **2** and **3**, the difference in absorptance between the first wavelength and the second wavelength, which may be referred to as a first difference, remains constant for the illumination light component and is variable for the pigment component. Considering this, the image capturing apparatus **100** relating to the present embodiment identifies the pigment component by referring to the difference between the first difference and a second difference, which denotes the difference in optical intensity of the light from the subject between the first wavelength and the second wavelength. The image capturing apparatus **100** then subtracts the identified pigment component from the subject image, thereby extracting the image of the illumination light component without influence of the pigment component of the subject.

Here, the first and second wavelengths may be set at 540 nm and 500 nm respectively. Alternatively, the first and second wavelengths may be set at 440 nm and 540 nm respectively. In these cases, the difference in absorptance between the first wavelength and the second wavelength also remains constant for the illumination light component and is variable for the pigment component. Therefore, the image capturing apparatus **100** can extract the image of the illumination light component from the subject image in a similar manner as in the case where the first and second wavelengths are set at 440 nm and 500 nm respectively.

FIG. **4** illustrates exemplary color components contained in the subject image obtained by the subject image obtaining section **126**. In FIG. **4**, intensities designated by the reference numerals **401**, **411** and **421** are the intensities of the respective color components in the subject image obtained by the subject image obtaining section **126**.

The intensity **401** is the intensity of the B component (420 nm to 490 nm) in the subject image. The intensity **411** is the intensity of the G component (490 nm to 600 nm) in the subject image. The intensity **421** is the intensity of the R component (600 nm to 750 nm) in the subject image.

Intensities designated by the reference numerals **402**, **412** and **422** are the intensities of the respective color components in the pigment component of the subject image, which is identified by the pigment component identifying section **120**. The intensity **402** is the intensity of the B component (420 nm to 490 nm) in the pigment component of the subject image. The intensity **412** is the intensity of the G component (490 nm to 600 nm) in the pigment component of the subject image. The intensity **422** is the intensity of the R component (600 nm to 750 nm) in the pigment component of the subject image. For example, the pigment component identifying section **120** can identify the intensities **402**, **412**, and **422**, based on the color information stored on the subject information storing section **124**.

In one example, the pigment component identifying section **120** first obtains the difference in the absorptance of the subject between the wavelength of 440 nm and the wavelength of 500 nm, that is to say, the first difference. Specifically speaking, the pigment component identifying section **120** obtains the first difference from a memory or the like that stores thereon the first difference. After this, the pigment component identifying section **120** calculates the difference in the optical intensity detected by the optical intensity detecting section **118** between the wavelength of the 440 nm and the wavelength of the 500 nm, that is to say, the second difference.

Subsequently, the pigment component identifying section **120** obtains from the subject information storing section **124** the color information associated with the obtained first difference and the calculated second difference. For example, the color information obtained from the subject information storing section **124** indicates the intensities of the B, G and R components. Thus, the pigment component identifying section **120** can identify the intensities **402**, **412**, and **422**, based on the color information stored on the subject information storing section **124**.

According to a different example, the pigment component identifying section **120** first obtains the difference in the absorptance of the subject between the wavelength of 440 nm and the wavelength of 500 nm, that is to say, the first difference. Specifically speaking, the pigment component identifying section **120** obtains the first difference from a memory or the like that stores thereon the first difference. After this, the pigment component identifying section **120** calculates the difference in optical intensity detected by the optical intensity detecting section **118** between the wavelength of 440 nm and the wavelength of 500 nm, that is to say, the second difference.

Subsequently, the pigment component identifying section **120** calculates a difference between the obtained first difference and the calculated second difference. The pigment component identifying section **120** obtains from the subject information storing section **124** the color information associated with the calculated difference. For example, the color information obtained from the subject information storing section **124** indicates the intensities of the B, G and R components. Thus, the pigment component identifying section **120** can identify the intensities **402**, **412**, and **422**, based on the color information stored on the subject information storing section **124**.

The pigment component identifying section **120** may identify the intensities **402**, **412**, and **422**, for each of the pixels of the subject image. Alternatively, the pigment component identifying section **120** may identify the intensities **402**, **412**, and **422**, for each of the partial regions of the subject image. For example, the pigment component identifying section **120** may identify the intensities **402**, **412**, and **422**, for each of the partial regions formed by 4×4, 8×8, or 16×16 pixels in the subject image.

Intensities designated by the reference numerals **403**, **413** and **423** are the intensities of the respective color components of the illumination light component in the subject image, which is identified by the illumination light component identifying section **122**. The intensity **403** is the intensity of the B component (420 nm to 490 nm) in the illumination light component of the subject image. The intensity **413** is the intensity of the G component (490 nm to 600 nm) in the illumination light component of the subject image. The intensity **423** is the intensity of the R component (600 nm to 750 nm) in the illumination light component of the subject image.

For example, the illumination light component identifying section **122** may calculate the intensity **403** of the B component in the illumination light component of the subject image, by subtracting the intensity **402** of the B component in the pigment component of the subject image from the intensity **401** of the B component in the subject image. The illumination light component identifying section **122** may calculate the intensity **413** of the G component in the illumination light component of the subject image, by subtracting the intensity **412** of the G component in the pigment component of the subject image from the intensity **411** of the G component in the subject image. The illumination light component identifying section **122** may calculate the intensity **423** of the R component in the illumination light component of the subject image, by subtracting the intensity **422** of the R component in the pigment component of the subject image from the intensity **421** of the R component in the subject image.

The illumination light component identifying section **122** may identify the intensities **403**, **413**, and **423**, for each of the pixels of the subject image. Alternatively, the illumination light component identifying section **122** may identify the intensities **403**, **413**, and **423**, for each of the partial regions of the subject image. For example, the illumination light component identifying section **122** may identify the intensities **403**, **413**, and **423**, for each of the partial regions formed by 4×4, 8×8, or 16×16 pixels in the subject image.

FIG. **5** illustrates exemplary partial regions, in each of which the pigment component and the illumination light component are identified. FIG. **5** shows the subject image obtained by the subject image obtaining section **126**. An image **500** includes partial regions **511**, **512**, **513** and **514**. Each partial region includes 4×4 pixels.

The pixel arrangement of the image **500** is merely an example of how to arrange the R, G and B components, and the present invention is not limited to such. The number of pixels in each partial region is not limited to 4×4, and can be 8×8 or 16×16.

The pigment component identifying section **120** may identify the pigment component in each of the partial regions **511**, **512**, **513** and **514**. For example, the pigment component identifying section **120** may identify the intensities of the R, G and B components of the pigment component, in each of the partial regions **511**, **512**, **513** and **514**.

The illumination light component identifying section **122** may identify the illumination light component in each of the partial regions **511**, **512**, **513** and **514**. For example, the illumination light component identifying section **122** may identify the intensities of the R, G and B components of the illumination light component, in each of the partial regions **511**, **512**, **513** and **514**.

FIG. **6** illustrates an example of the subject image obtained by the subject image obtaining section **126**. A subject image **600** shows a protrusion portion **601**, an influenced region **602** and an influenced region **603**.

In the subject image **600**, the protrusion portion **601** is positioned in a relatively bright region. Therefore, an observer such as a medical doctor can refer to the subject image **600** to accurately diagnose the condition of the protrusion portion **601**. In the subject image **600**, on the other hand, the influenced regions **602** and **603** are positioned in a relatively dark region, and darkened under the influence of the pigment of the subject. Therefore, an observer such as a medical doctor cannot refer to the subject image **600** to accurately diagnose the condition of the surface of the subject in the influenced portions **602** and **603**.

FIG. **7** illustrates an example of the image generated by the illumination light image generating section **132**. An image **700** is of the illumination light component, and is generated by subtracting the color information of the pigment component identified by the pigment component identifying section **120** from the color information of the subject image **600** shown in FIG. **6**.

Since the color information of the pigment component has been subtracted, the image **700** no longer includes the influenced regions **602** and **603**, which are present in the subject image **600**. Therefore, the image **700** visibly shows a protrusion portion **701**. As a consequence, an observer such as a medical doctor can refer to the image **700** to accurately diagnose the condition of the protrusion **701**.

FIG. **8** illustrates an exemplary hardware configuration of the image capturing apparatus **100**. The image capturing apparatus **100** is constituted by a CPU surrounding section, an input/output (I/O) section and a legacy I/O section. The CPU surrounding section includes a CPU **1505**, a RAM **1520**, a graphic controller **1575**, and a display device **1580** which are connected to each other by means of a host controller **1582**. The I/O section includes a communication interface **1530**, a hard disk drive **1540**, and a CD-ROM drive **1560** which are connected to the host controller **1582** by means of an I/O controller **1584**. The legacy I/O section includes a ROM **1510**, a flexible disk drive **1550**, and an I/O chip **1570** which are connected to the I/O controller **1584**.

The host controller **1582** connects the RAM **1520** with the CPU **1505** and graphic controller **1575** which access the RAM **1520**. The CPU **1505** operates in accordance with programs stored on the ROM **1510** and RAM **1520**, to control the constituents. The graphic controller **1575** obtains image data which is generated by the CPU **1505** or the like on a frame buffer provided within the RAM **1520**, and causes the display device **1580** to display the obtained image data. Alternatively, the graphic controller **1575** may include therein a frame buffer for storing thereon image data generated by the CPU **1505** or the like.

The I/O controller **1584** connects, to the host controller **1582**, the hard disk drive **1540**, communication interface **1530** and CD-ROM drive **1560** which are I/O devices operating at a relatively high rate. The hard disk drive **1540** stores thereon programs and data to be used by the CPU **1505**. The communication interface **1530** couples to the network communication apparatus **1598**, to transmit/receive programs or data. The CD-ROM drive **1560** reads programs or data from a CD-ROM **1595**, and supplies the read programs or data to the hard disk drive **1540** and communication interface **1530** via the RAM **1520**.

The I/O controller **1584** is also connected to the ROM **1510**, flexible disk drive **1550** and I/O chip **1570** which are I/O devices operating at a relatively low rate. The ROM **1510** stores thereon a boot program executed by the image capturing apparatus **100** at the start up, programs dependent on the hardware of the image capturing apparatus **100** and the like. The flexible disk drive **1550** reads programs or data from a flexible disk **1590**, and supplies the read programs or data to the hard disk drive **1540** and communication interface **1530** via the RAM **1520**. The I/O chip **1570** is used to connect a variety of I/O devices such as the flexible disk drive **1550** via, for example, a parallel port, a serial port, a keyboard port, a mouse port or the like.

The program to be executed by the CPU **1505** is provided by a user in the state of being stored on a recording medium such as the flexible disk **1590**, the CD-ROM **1595**, and an IC card. The program may be stored on the recording medium in the state of being compressed or not being compressed. The program is installed from the recording medium onto the hard disk drive **1540**, read by the RAM **1520**, and executed by the CPU **1505**. The program executed by the CPU **1505** causes the image capturing apparatus **100** to function as the respective constituents of the image capturing apparatus **100** described with reference to FIGS. **1** to **7**.

The program mentioned above may be stored on an external recording medium. The recording medium is, for example, an optical recording medium such as DVD and PD, a magnet-optical recording medium such as MD, a tape medium, a semiconductor memory such as an IC card and the like, in addition to the flexible disk **1590** and CD-ROM **1595**. The recording medium may be a storage device such as a hard disk or RAM which is provided in a server system connected to a dedicated communication network or the Internet, and the program may be provided to the image capturing apparatus **100** via the network.

Although some aspects of the present invention have been described by way of exemplary embodiments, it should be understood that those skilled in the art might make many changes and substitutions without departing from the spirit and the scope of the present invention which is defined only by the appended claims.

The claims, specification and drawings describe the processes of an apparatus, a system, a program and a method by using the terms such as operations, procedures, steps and stages. When a reference is made to the execution order of the processes, wording such as "before" or "prior to" is not explicitly used. The processes may be performed in any order unless an output of a particular process is used by the following process. In the claims, specification and drawings, a flow of operations may be explained by using the terms such as "first" and "next" for the sake of convenience. This, however, does not necessarily indicate that the operations should be performed in the explained order.

What is claimed is:

1. A signal processing apparatus for separating light from a specified subject into an illumination light component and a pigment component, the illumination light component resulting from a color of light with which the subject is irradiated, the pigment component resulting from a color of a pigment of the subject, the signal processing apparatus comprising a processor, the processor including a program stored therein for causing the processor to perform executable sections, the executable sections comprising:

a subject image obtaining section that obtains a subject image including R, G, and B components;

an optical intensity detecting section that detects an intensity of the light from the subject at a first wavelength and a second wavelength, the first wavelength being different from the second wavelength;

a pigment component identifying section that identifies the pigment component of the subject image, based on a difference between a first absorptance of the subject at the first wavelength and a second absorptance of the subject at the second wavelength, and a difference between an intensity at the first wavelength and an intensity at the second wavelength that are detected by the optical intensity detecting section;

an illumination light component identifying section that identifies the illumination light component of the subject image, based on the subject image and the pigment component identified by the pigment component identifying section,

wherein the optical intensity detecting section detects the intensity of the light from the subject at the first wavelength, at which a light absorption characteristic of the subject takes a minimal value and at the second wavelength, at which the light absorption characteristic of the subject takes a maximal value;

a subject information storing section that stores color information of the subject indicating intensities of respective R, G and B components in association with the difference between the first absorptance and the second absorptance of the subject and the difference between the detected intensity at the first wavelength and the detected intensity at the second wavelength,

wherein the pigment component identifying section identifies intensities for respective R, G and B components of the pigment component of the subject image, based on the color information stored in the subject information storing section, and

wherein the illumination light component identifying section identifies intensities for respective R, G and B components of the illumination light component of the subject image, by subtracting intensities for respective R, G, and B components of the pigment component identified by the pigment component identifying section from intensities for respective R, G, and B components of color information of the subject image; and

an illumination light image generating section that generates an image of the illumination light component identified by the illumination light component identifying section, by subtracting color information of the pigment component identified by the pigment component identifying section from the color information of the subject image obtained by image-capturing the subject.

2. The signal processing apparatus as set forth in claim **1**, wherein the optical intensity detecting section detects the intensity of the light from the subject at the first and second wavelengths in each of partial regions obtained by dividing the subject image,

wherein the pigment component identifying section identifies the pigment component of the subject image in each of the partial regions, and

wherein the illumination light component identifying section identifies the illumination light component of the subject image in each of the partial regions.

3. The signal processing apparatus as set forth in claim **2**, further comprising:

an illumination light component enhancing section that enhances, in the subject image obtained by image-capturing the subject, color information of the illumination light component identified by the illumination light component identifying section.

4. The signal processing apparatus as set forth in claim 2, further comprising:

a pigment component enhancing section that enhances, in the subject image obtained by image-capturing the subject, color information of the pigment component identified by the pigment component identifying section.

5. The signal processing apparatus as set forth in claim 1, wherein, in said signal processing apparatus, the intensity of the light from the subject increases prior to the first wavelength that the light absorption characteristic of the subject takes the minimal value, and

wherein, in said signal processing apparatus, the intensity of the light from the subject decreases after the second wavelength that the light absorption characteristic of the subject takes the minimal value.

6. The signal processing apparatus as set forth in claim 5, wherein, in said signal processing apparatus, the intensity of the light from the subject decreases prior to the first wavelength that the light absorption characteristic of the subject takes the maximal value, and

wherein, in said signal processing apparatus, the intensity of the light from the subject increases after the second wavelength that the light absorption characteristic of the subject takes the maximal value.

7. The signal processing apparatus as set forth in claim 1, wherein, in said signal processing apparatus, a frequency characteristic of the illumination light component of the subject image is independent of an intensity of irradiation light with which the subject is irradiated.

8. The signal processing apparatus as set forth in claim 1, wherein, in said signal processing apparatus, the difference between the first absorptance of the subject at the first wavelength and the second absorptance of the subject at the second wavelength is constant for the illumination light component.

9. The signal processing apparatus as set forth in claim 8, wherein, in said signal processing apparatus, the difference between the first absorptance of the subject at the first wavelength and the second absorptance of the subject at the second wavelength is variable for the pigment component.

10. The signal processing apparatus as set forth in claim 1, wherein, in said signal processing apparatus, the intensity of the light from the subject changes before and after the first wavelength and the second wavelength.

11. A signal processing method for separating light from a specified subject into an illumination light component and a pigment component, the illumination light component resulting from a color of light with which the subject is irradiated, the pigment component resulting from a color of a pigment of the subject, the signal processing method comprising:

obtaining a subject image including R, G, and B components;

detecting an intensity of the light from the subject at a first wavelength and a second wavelength, the first wavelength being different from the second wavelength;

identifying the pigment component of the subject image, based on a difference between a first absorptance of the subject at the first wavelength and a second absorptance of the subject at the second wavelength, and a difference between an intensity at the first wavelength and an intensity at the second wavelength that are detected in the intensity detecting;

identifying the illumination light component of the subject image, based on the subject image and the pigment component identified in the pigment component identifying,

wherein said detecting comprises detecting the intensity of the light from the subject at the first wavelength, at which a light absorption characteristic of the subject takes a minimal value and at the second wavelength, at which the light absorption characteristic of the subject takes a maximal value;

storing color information of the subject indicating intensities of respective R, G and B components in association with the difference between the first absorptance and the second absorptance of the subject and the difference between the detected intensity at the first wavelength and the detected intensity at the second wavelength,

wherein the identifying the illumination light component comprises identifying intensities for respective R, G and B components of the pigment component of the subject image, based on the color information stored in the storing color information, and

wherein, said identifying the illumination light component comprises identifying intensities for respective R, G and B components of the illumination light component of the subject image, by subtracting intensities for respective R, G, and B components of the identified pigment component from intensities for respective R, G, and B components of color information of the subject image; and

generating, by a processor of a computer, an image of the identified illumination light component by subtracting color information of the identified pigment component from the color information of the subject image.

12. The signal processing method as set forth in claim 11, wherein the intensity of the light from the subject changes before and after the first wavelength and the second wavelength.

13. A non-transitory computer readable medium storing thereon a program for use with a signal processing apparatus that separates light from a specified subject into an illumination light component and a pigment component, the illumination light component resulting from a color of light with which the subject is irradiated, the pigment component resulting from a color of a pigment of the subject, the program causing a computer to perform functions in executable sections, the executable sections comprising:

a subject image obtaining section that obtains a subject image including R, G, and B components;

an optical intensity detecting section that detects an intensity of the light from the subject at a first wavelength and a second wavelength, the first wavelength being different from the second wavelength;

a pigment component identifying section that identifies the pigment component of the subject image, based on a difference between a first absorptance of the subject at the first wavelength and a second absorptance of the subject at the second wavelength, and a difference between an intensity at the first wavelength and an intensity at the second wavelength that are detected by the optical intensity detecting section;

an illumination light component identifying section that identifies the illumination light component of the subject image, based on the subject image and the pigment component identified by the pigment component identifying section,

wherein the optical intensity detecting section detects the intensity of the light from the subject at the first wavelength, at which a light absorption characteristic of the subject takes a minimal value and at the second wavelength, at which the light absorption characteristic of the subject takes a maximal value;

a subject information storing section that stores color information of the subject indicating intensities of respective R, G and B components in association with the difference between the first absorptance and the second absorptance of the subject and the difference between the detected intensity at the first wavelength and the detected intensity at the second wavelength,

wherein the pigment component identifying section identifies intensities for respective R, G and B components of the pigment component of the subject image, based on the color information stored in the subject information storing section, and

wherein the illumination light component identifying section identifies intensities for respective R, G and B components of the illumination light component of the subject image, by subtracting intensities for respective R, G, and B components of the pigment component identified by the pigment component identifying section from intensities for respective R, G, and B components of color information of the subject image; and

an illumination light image generating section that generates an image of the illumination light component identified by the illumination light component identifying section, by subtracting color information of the pigment component identified by the pigment component identifying section from the color information of the subject image obtained by image-capturing the subject.

14. The non-transitory computer readable medium as set forth in claim **13**, wherein, in said signal processing apparatus, the intensity of the light from the subject changes before and after the first wavelength and the second wavelength.

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